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Characterization of Indoor Sources of Air Contaminants: Report on a Technical Conference

John B. Pierce Foundation Lab., New Haven, CT

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Environmental Protection Agency
Research Triangle Park, NC

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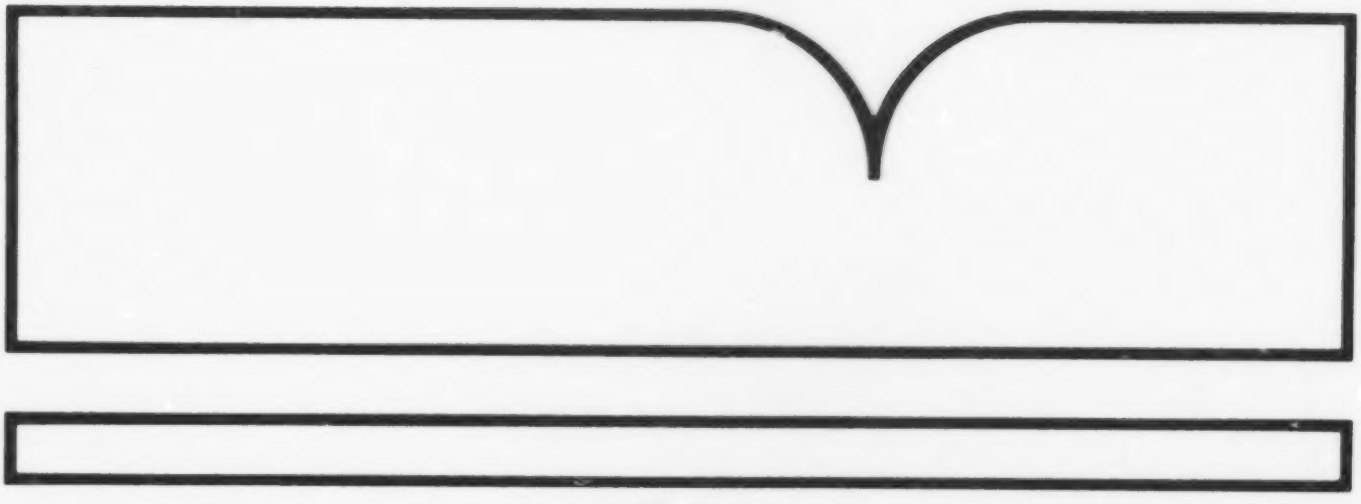

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16. ABSTRACT The report describes a technical conference, "Characterization of Contaminant Emissions from Indoor Sources," held in Chapel Hill, NC, May 13-15, 1985, to assess the status of methodological issues in the laboratory and field evaluation of air contaminants from indoor sources. A total of 29 invited papers were presented in five technical sessions during the 3-day conference. A sixth session was a panel discussion summarizing the conference findings, led by the conference chairman and the five session chairmen. The papers presented at the conference and the session summaries, written by the session chairmen, have been published in Atmospheric Environment, Vol. 21, No. 2, February 1987. This report contains a description of the purpose of the conference, a conference program, abstracts of the papers presented, a list of attendees, and a conference review.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
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Atmosphere Contamination Control	Formaldehyde	Stationary Sources		07C
	Residential Buildings	Indoor Air	06K	13M
Emission	Construction Materials	Consumer Products	14G	13C
Radon	Organic Compounds	Volatile Organics	07B	
Combustion	Bioassay		21B	06A, 06O

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CHARACTERIZATION OF INDOOR SOURCES OF AIR CONTAMINANTS: REPORT ON A TECHNICAL CONFERENCE

by

Brian P. Leaderer
John B. Pierce Foundation Laboratory, Inc.
290 Congress Avenue
New Haven, Connecticut 06519

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Project Officer

David C. Sanchez
Indoor Air Branch
Air and Energy Engineering Research Laboratory
United States Environmental Protection Agency
Research Triangle Park, N.C. 27711

AIR AND ENERGY ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

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ABSTRACT

The characterization of indoor sources of air contaminants has employed a wide variety of test protocols and sampling and analytical methods in both laboratory and field studies. A technical conference entitled "Characterization of Contaminant Emissions from Indoor Sources" was held in Chapel Hill, NC, May 13-15, 1985, to assess the status of methodological issues in the laboratory and field evaluation of air contaminants from indoor sources. A total of 29 invited papers was presented in five technical sessions during the three day conference. A sixth session was a panel discussion summarizing the conference findings, led by the conference chairman and the 5 session chairmen. The papers presented at the conference and the session summaries, written by the session chairpersons, have been published in Atmospheric Environment Volume 21, No. 2, February 1987. This report contains a description of the purpose of the conference, a conference program, abstracts of the papers presented, a list of attendees and a conference review.

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INTRODUCTION

Efforts to reduce energy consumption over the past several years have fostered a number of energy saving strategies in residences (e.g., weatherization of homes and the use of supplemental space heaters). These strategies have focused concern on the air quality in the non-occupational residential environment because of the potential for high exposures to a large number of air contaminants. Unvented kerosene space heaters, which have come into popular use in residences (over 10 million were sold in the last four years), have been shown to potentially result in exposures to several important air contaminants (CO, SO_2, NO_2, etc.) in excess of ambient air quality standards and in some cases in excess of occupational health standards (1-6). One recent study found an association between kerosene heater use and adverse health effects in children (7). Concentrations of formaldehyde in residences resulting from emissions of building materials, insulation and building furnishings are suspected of causing adverse health effects in residents (8,9). Gas cooking appliances have been demonstrated to result in nitrogen dioxide levels in excess of the ambient standards (6,10,11). Recently, there have been a number of published studies relating passive smoking to adverse health effects in non-smokers (12-19). Several studies have demonstrated that air contaminants associated with sidestream smoke (both exhaled mainstream and sidestream emissions) from tobacco combustion will result in contaminant concentrations in occupied spaces in excess of ambient air quality standards and in odor levels unacceptable to visitors (20-25). A substantial increase in ventilation rates or the introduction of air cleaning devices is needed to produce acceptable air quality

in spaces where smoking is permitted (22,23). Radon progeny exposures in residences, resulting from radon contaminated soil, building substructure and drinking water, have been estimated to result in excess lung cancer deaths each year (26,27). The Total Exposure Assessment Methodology (TEAM) Study, conducted by the U.S. Environmental Protection Agency, demonstrated the importance of the indoor residential environment in personal exposures to 20 selected toxic, carcinogenic or mutagenic organic compounds (28).

Air contaminant levels in the indoor-non-industrial environment are the result of a complex interaction of several interrelated variables including:

a. The type, nature (factors affecting the emission rate) and number of sources;
b. source use characteristics;
c. building characteristics (type of construciton, volume, etc.);
d. infiltration rates;
e. air mixing within a residence;
f. sink or loss terms (removal of contaminants by surfaces or chemical trans-formations);
g. existence and effectiveness of air contaminant control systems;
h. outdoor concentrations of the contaminant; and,
i. meteorological conditions.

The interaction of these variables in determining the resultant indoor concentrations, and hence exposure, have typically been evaluated within the theoretical framework of the general mass balance equation (although some simple empirical statistical models have been employed) (3,4,21,24,30-41).

Detailed information on the first two variables, relating to indoor source air contaminant emissions, is essential in assessing the nature and extent of indoor air contaminant exposures.

Contaminants found in indoor air comprise a broad spectrum of organic and inorganic chemicals in gaseous and particulate forms, as well as a range of viable particulates. These contaminants migrate in from outdoors, may be generated by activities of the occupants, or may be released from the building or its contents. Air contaminants associated with human activities indoors arise from tobacco smoking, cooking, space heating, use of propellants, etc. Indoor contaminants generated from building materials and building furnishings include formaldehyde, radon and radon progeny, asbestos, phthalates, etc. The sources of these contaminants have only been partially characterized despite the fact that an adequate physical and chemical characterization of indoor sources is needed to:

a) identify the major sources and the factors controlling the release of air contaminants from them;

b) quantify their impact on total indoor exposures;

c) develop source use emission models to guide field study desgins;

d) develop effective mitigation measures to reduce or eliminate the emissions and hence the exposures.

Indoor sources can be characterized as being either point or area in nature and show little or considerable variation in time. Environmental factors (temperature, humidity) and personal habits related to source use can have a major impact on the type of air contaminants generated and their emission rates.

Efforts to physically, chemically and biologically characterize emissions

from indoor sources have employed a wide variety of test protocols and sampling and analytical methods. There is no consensus on source characterization methodology or the priority of sources to be evaluated, nor does there exist a compilation of current emission factors, despite the importance of source characterization in assessing indoor air quality. Some sources, particularly unvented kerosene space heaters, have been extensively evaluated for emissions of specific air contaminants under a variety of testing protocols, while other sources (i.e. consumer products) have received little or no attention despite their importance. Some categories of indoor air contaminants (e.g., NO_2, CO, HCHO) have been the object of intensive evaluation to characterize their sources while other categories of air contaminants (e.g., biological aerosols) have received only marginal attention. Differences in test protocols (e.g., head space analysis vs. chamber studies, or chamber studies vs. test house studies) have led to discrepancies in emission factors developed for specific air contaminants from individual sources. Source testing or evaluation by bioassay methods and sensory responses (odor, eye irritation, etc.) is only just beginning. The role of laboratory based studies (headspace analysis, chamber studies and test house studies) in designing the protocols for large scale field studies of indoor air contaminants needs to be clearly defined. The laboratory studies are critical to field studies in designing the questionnaire to be used, the air sampling protocols, interpreting the air contaminant measurements made and in developing broadly applicable indoor exposure predictive models. A critical comparison of the source assessment methods used in recently completed and ongoing large scale field studies has not yet been undertaken. The interaction or relationship between laboratory and large scale field based studies needs to be explored.

Current efforts by the private and public sectors to characterize air contaminant emissions from indoor sources have addressed only a few of the sources and employed a wide range of experimental protocols utilizing a variety of sampling and analytical methodologoy. There is currently no standardized methodology employed for source characterization efforts nor is there a consensus among the scientific community of the current state of knowledge in the field or what directions future research should take.

The overall objective of this research project is to provide the U.S. Environmental Protection Agency (EPA) and the scientific community as a whole with the current state of knowledge in assessing air contaminant emissions from indoor sources and a critical review of the research protocols and sampling and analytical methodology employed to evaluate those sources. This objective was addressed through organizing and conducting a working conference on the characterization of contaminant emissions from indoor sources to which recognized experts would be invited to present papers on their current work. The conference design permitted a gathering of the research community actively working on indoor air source characterization to assess the current state of knowledge and future research needs. In order to encourage high quality presentations and to insure a wide distribution of both the papers presented and follow-up discussions to the scientific community as a whole, the papers and summaries of the sessions were published in a scientific journal (Atmospheric Environment, Volume 21, No 2, Februry 1987). This report will briefly describe the conference and attempt to highlight the major findings that ensued.

CONFERENCE

A small, working conference to accomplish the goals stated above was held in Chapel Hill, N.C., on May 13, 14, and 15, 1985. The conference was entitled CHARACTERIZATION OF CONTAMINANT EMISSIONS FROM INDOOR SOURCES. There were a total of 24 invited papers and five additional presentations from the floor. The papers were presented in five half-day sessions. Each of the sessions was designed to address a major methodological issue in indoor air source characterization. Five 20-minute invited presentations by researchers well known in their field were made in each session. A period of 10 minutes was allotted for questions from the floor after each paper and a 45 to 60 minute period in each session was allotted for general discussion from the floor and short presentations from the conference participants who desired to do so. The major purpose of the general discussion period was to attempt to reach a consensus on the general issues addressed in the session. The presenters of each paper were asked to provide a short abstract prior to the conference and a full length paper for submittal to a peer-reviewed journal shortly after the conference. A chairman for each of the five sessions was designated. The chairmen were senior individuals in their respective fields and had the responsibility of running their session. Their major responsibility was to guide the discussion period and summarize the major issues addressed, identify those issues for which a consensus had been reached, identify major areas of disagreement and to specify future research needs. The session chairmen were also required to provide a written summary of their session following the conference for inclusion in the peer-reviewed journal issue devoted to the conference papers. The final half-day session (sixth) of the conference was a panel discussion summarizing the

conference findings and involving the conference chairman and the five session chairmen. In addition to the aforementioned personnel, there were approximately thirty additional conference attendees who were invited to the conference due to their active research in the field of indoor air quality.

Appendix A contains a copy of technical program for the conference, Appendix B contains the abstracts for the papers presented at the conference, and Appendix C lists the names, affiliations, addresses and phone numbers of all the conference participants.

CONFERENCE OVERVIEW

The papers presented at the conference touched upon a wide range of issues relevant to the characterization of air contaminant emissions from indoor sources. The Atmospheric Environment journal volume devoted to the conference provides the best assessment of the current state of knowledge in the area of indoor air source characterization and indication of future research needs. I will attempt, here, to identify what I perceived to be the major general observations, comments and recommendations which emerged from the extensive discussion that occurred. It should be clearly noted that the following points do not represent a consensus of the conference participants, and are biased by my perspective.

1. The ultimate goal of indoor air source characterization is the protection of public health and welfare. Source characterization should identify and quantify air contaminants which may impact public health and comfort so that human exposure,

with associated adverse effects, may be assessed and mitigation methods be developed.

2. NO_x, CO, CO_2, SO_2 and HCHO emissions from unvented kerosene and gas space heaters and gas cooking stoves have been well characterized under conditions of a controlled environment (chamber) for appliances typically well tuned and used in standard, reproducible ways. Little is known about emissions of particulates (physical and chemical characteristics) and VOCs for these appliances. In addition, little is known about the variability of emission rates from these appliances under the wide range of use categories observed in residences. Inexpensive, quick and easy-to-use methodologies need to be developed which would permit the measurement of emission rates for important air contaminants from these unvented combusion sources in large scale field studies, in order to determine the distribution of emission rates under "real world" conditions.

3. While a good deal is known about mainstream emissions of air contaminants from tobacco combustion, little is known about environmental emissions from tobacco combustion (sidestream plus exhaled mainstream). ETS (environmental tobacco smoke) is a major indoor air contaminant and as such should be a high priority in source characterization efforts.

4. One important objective of source characterization is to identify the range of source operating conditions which may impact emissions such that field study "tools" can be developed for use in large scale field studies. These "tools" include source identification and source use questions for inclusion in field study questionnaires (including daily source use diaries) and air sampling protocols. The link between chamber, test house and large scale field studies for source characterization needs to be firmly established and coordinated.

5. The identification prioritization and development of experimental methodologies for screening building materials and furnishings for emissions of volatile organic compounds (VOCs) is just beginning. The enormous number of materials in the indoor enviroment with a broad range of VOC emissions makes this effort important. There is also a critical need to develop an approach to characterizing VOCs in indoor air which eficiently employs screening, chamber, test house and field studies - no such methodology currently exists.

6. Consumer products represent a major category of sources of indoor air contaminants which present unique methodology problems. The development of methodologies for evaluating emissions from this category of sources has just been initiated and should be continued.

7. The identification and characterization of sources of bioaerosols indoors has received little attention despite the importance of bioaerosols as an indoor air contaminant. An increased research effort in this area is needed.

8. Micro-bioassay measurement methodologies are just becoming available for use in characterizing indoor sources of air contaminants and may provide a useful means of assessing sources based upon their biological activity.

9. The characterization of indoor sources by sensory evaluation techniques has been applied to human body odor and environmental tobacco smoke sources. This methodology could prove useful in evaluating a number of other sources, particularly sources of VOCs.

10. The modeling of exposures to indoor air contaminants will require accurate source emission rate inputs and the identification of a suitable proxy or tracer air contaminant for complex sources if the models are to be useful. Source characterization efforts are essential to identify the proxy air contaminants for sources and to provide realistic and accurate emission rates for the contaminants of interest.

CONCLUSION

This conference initiated a scientific dialogue among researchers working in the area of indoor air source characterization. For the first time, this scientific community was able to assess the current state of knowledge in the field and identify future needs. As is usually the case in such discussions, more questions were raised than were answered. The highly structured framework which the conference employed produced the type and quality of information needed by EPA and the general research community in characterizing indoor sources of air contaminants. The publication of the conference proceedings in a peer reviewed journal ensured both the quality of information presented and wide distribution to the scientific community. This conference started a dialogue among scientists in this field which should be continued. Methods for ensuring a continuation of this dialogue, including future conferences with a similar structure, should be pursued.

REFERENCES

1. Consumer Product Safety Commission. Kerosene heaters status report and staff recommendations. Washington, D.C.: Consumer Product Safety Commission, 1983.

2. Leaderer, B.P. Air pollutant emissions from kerosene heaters. Science 218: 1113-1115, 1982.

3. Traynor, G.W., Allen, J.R., Apte, M.G., Girman, J.R., and Hollowell, C.D. Pollutant emissions from portable kerosene-fired space heaters. Environmental Science and Technology 17: 327-332, 1983.

4. Yamanaka, S., Hirose, H., and Takada, S. Nitrogen oxides emissions from domestic kerosene-fired and gas-fired appliances. Atmospheric Environment 13: 407-412, 1979.

5. Leaderer, B.P., Zagraniski, R.T., Berwick, M., Stolwijk, J.A.J. and Ma, Q. Residential exposures to NO_2, SO_2 and HCHO associated with unvented kerosene space heaters, gas appliances and sidestream tobacco smoke. In B. Berglund, T. Lindvall and J. Sundell (Eds.), Indoor Air, Vol. 4, Chemical Characterization and Personal Exposure. Stockholm: Swedish Council for Building Research, 151-156, 1984.

6. Leaderer, B.P., Zagraniski, R.T., Berwick, M. and Stolwijk, J.A.J. Assessment of exposure to indoor air contaminants from combustion sources: methodology and application. American Journal of Epidemiology. Vol. 117, 1986.

7. Berwick, M., Zagraniski, R.T., Leaderer, B.P. and Stolwijk, J.A.J. Respiratory illness in children exposed to unvented combustion sources. In B. Berglund, T. Lindvall and J. Sundell (Eds.), Indoor Air, Vol. e, Radon Passive Smoking, Particulates and Housing Epidemiology. Stockholm: Swedish Council for Building Research, 255-260, 1984.

8. Committee on Aldehydes. Formaldehyde and Other Aldehydes. National Academy Press, Washington, D.C., 1981.

9. Committee on Indoor Pollutants. Indoor Pollutants. National Academy Press, Washington, D.C., 1981.

10. Spengler, J.D., Duffy, C., Letz, R., Tibbitts, T.W. and Ferris, Jr, B.G. Nitrogen dioxide inside and outside 137 homes and implications for ambient air quality standards and health effects research. Environmental Science and Technology 17: 164-168, 1983.

11. Goldstein, I., Hartel, D. and Andrews, L. Indoor exposure of asthmatics to nitrogen dioxide. Proceedings of the Third International Conference on Indoor Air Quality and Climate, 1984, Vol. 2, pp. 269-274.

12. Correa, P., Pickle, L.W., Fontham, L., Lin, Y. and Haensel, W. Passive smoking and lung cancer. Lancet 12: 595-597, 1983.

13. Hirayama, T. Lung cancer in Japan: Effects of nutrition and passive smoking. In Lung Cancer: Causes and Prevention. M. Mizell, P. Correa (Eds.). Verlag, Chemie International: New York, pgs, 175-195, 1984.

14. Garland, C., E. Barrett-Connor, L. Suarez, M.H. Crique, D.L. Wingard. Effects of passive smoking on ischemic heart disease mortality of nonsmokers: a prospective study. Amer. J. Epi. 121: 645-650, 1985.

15. Wu, A.H., B.E. Henderson, M.C. Pike, M.C. Yu. Smoking and other risk factors for lung cancer in women. J. Nat. Cancer Inst. 74: 747-751, 1985.

16. White, J.R., and Froeb, H.F. Small-airways dysfunction in nonsmokers chronically exposed to tobacco smoke. New England Journal of Medicine 302: 720, 1980.

17. Lewitter, F.I., Tager, I.B., McGue, M. Tishler, P.V. and Speizer, F.E. Genetic and environmental determinations of levels of pulmonary function. American Journal of Eplidemiology 120: 518-530, 1984.

18. Kauffmann, F., Tessier, J.F. and Oriol, P. Adult passive smoking in the home environment: A risk factor for chronic airflow limitations. American Journal of Epidemiology 117: 269-280, 1983.

19. Trichopoulos, D., Kalendid, A., Sparros, L. and McMahon, B. Lung cancer and passive smoking. Int. J. Cancer 27: 1-4, 1981 and Trichopoulos, D. Passive smoking and lung cancer. Lancet i: 684, 1984.

20. Repace, J.L., Lowrey, A.H. Indoor air pollution, tobacco smoke, and public health. Science 208: 464-472, 1980.

21. Repace, J.L., Lowrey, A.H. Tobacco smoke, ventilation and indoor air quality. ASHRAE Transactions 88: 894-914, 1982.

22. Cain, W.S., Leaderer, B.P., Isseroff, R., Berglund, L.G., Huey, R.J., Lipsitt, E. and Perlman, D. Ventilation requirements in buildings I: Control of occupancy odor and tobacco smoke odor. Atmos. Environ., 1983, Vol. 17, No. 6, 1183-1197.

23. Leaderer, B.P., Cain, W.S., Isseroff, R. and Berglund, L.G. Ventilation requirements in buildings II: Particulate matter and carbon monoxide from cigarette smoking. Atmos. Environ., 1984, Vol. 17, No. 12, pp. 99-106.

24. Muramatsu, T., Weber, A., Muramatsu, S. and Akermann, F. Experimental study on irritations and annoyance due to passive smoking. International Archives of Occupational and Environmental Health 51: 305-317, 1983.

25. Spengler, J.D., Treitman, R.D., Tosteson, T.D., Mage, D.T. and Soczek, M.L. Personal exposures to respirable particulates and implications for air pollution epidemiology. Env. Sci. & Technol. 19:700-706, 1985.

26. Evans, R., Harley, J.H., Jacobi, W., McLean, A.S., Mills, W.A. and Stewart, C.G. Estimate of risk from environmental exposure to radon-222 and its decay products. Nature 290: 98-100, 1981.

27. Burkart, W. Assessment of radiation dose and effects from radon and its progeny in energy-efficient homes. Nuclear Technol. 60: 114-123, 1983.

28. Wallace, L., Pellizzari, E., Hartwell, T., Rosenzweig, M., Erickson, M., Sparacino, C. and Zelon, H. Personal exposure to volatile organic compounds: I. Direct measurements in breathing-zone air, drinking water, food and exhaled breath. Environmental Research, 35:193-211, 1984.

29. Turk, A. Measurements of odorous vapors in test chamber: Theoretical ASHRAE 9(5): 55-8, 1963.

30. Esmen, N.A. Characterization of contaminant concentrations in enclosed spaces. Environ. Sci. Technol. 12: 337-339, 1978.

31. Ishizu, Y. General equation for the estimation of indoor pollution. Environ. Sci. Technol. 14: 1254-1257, 1980.

32. Kusuda, T., Silberstein, S. and McNall, P.E. Modeling of radon and its daughter concentrations in ventilated spaces. APCA, 30: 1201-1207, 1980.

33. Dockery, D.W. and Spengler, J.D. Indoor-outdoor relationships of respirable sulfates and particulates. Atmos. Environ. 15: 335-338, 1981.

34. Shair, F.H. and Heitner, K.L. Theoretical model for relating indoor pollutant concentrations to those outside. Environ. Sci. and Tech. 8: 444-451, 1974.

35. Sexton, K., Letz, R. and Spengler, J.D. Estimating human exposure to nitrogen dioxide: An indoor/outdoor modeling approach. Environmental Research, 32: 151-166, 1983.

36. Ryan, P.B., Spengler, J.D. and Letz, R. The effects of kerosene heaters on indoor air quality: A monitoring and modeling study. Atmospheric Environment 17: 1339-1345, 1983.

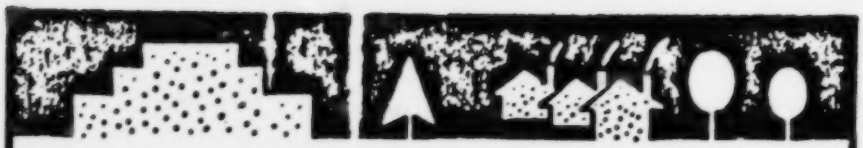
37. Matthews, T.G. Environmental chamber test methodology for organic vapors from solid emission sources. Atmospheric Environment, 20: 1986.

38. Moschandreas, D.J., Relwani, S.M., Billick, I.H. and Macriss, R.A. Emission rates from range top burners - assessment of measurement methods. Atmospheric Environment, 20: 1986.

39. Traynor, G.W. Field monitoring design considerations for assessing indoor exposures to combustion pollutants. Atmospheric Environment, 20: 1986.

40. Leaderer, B.P., Zagraniski, R.T., Berwick, M., Freeman, D., and Stolwijk, J.A.J. Predicting NO_2 levels in residences based upon sources and source use: A multivariate model. Atmospheric Environment, 20: 1986.

41. Renes, S., Leaderer, B.P., Schaap, L. Verstraelen and Tosun, T. "An evaluation of sink terms in removing NO_2 and SO_2 from indoor air". In P.O. Fanger (Ed). CLIMA 2000, Vol. 4, Indoor Climate, VVS Kongrea - VVS Messe, Copenhagen, 221-226, 1985.



CHARACTERIZATION OF CONTAMINANT EMISSIONS FROM INDOOR SOURCES

May 13-15, 1985

Hotel Europa

Chapel Hill, North Carolina

Sponsors:

The Air and Energy Engineering Research Laboratory of the U.S. Environmental Protection Agency

The Electric Power Research Institute

The Gas Research Institute

MONDAY, MAY 13

8:00 a.m. Registration

8:30 a.m. WELCOME and OPENING REMARKS
Brian P. Leaderer, Conference Chairman
John B. Pierce Fndn. Lab. & Yale University, Dept. of E.P.H.

Frank T. Princiotta
U.S. EPA (Director, AEERL)

SESSION I.

CHARACTERIZATION OF EMISSIONS FROM COMBUSTION SOURCES IN THE LABORATORY SETTING

Chair: Gene Tucker,
U.S. EPA (AEERL)

8:45 a.m. *Emissions from Unvented Combustion Sources*
Warren K. Porter, Jr.,
U.S. Consumer Product Safety Commission

9:15 a.m. *Emission Rates of Inorganic and Organic Air Constituents from Unvented Indoor Combustion Sources*
Demetrios J. Moschandreas,
IIT Research Institute

9:45 a.m. *Measuring Environmental Emissions from Tobacco Combustion*
Michael Guerin, C.E. Higgins, S.K. Holladay and R.A. Jenkins
Oak Ridge National Laboratory

10:15 Refreshment Break

10:30 a.m. *The Use of Laboratory-Derived Emission Factors for Predicting Pollutant Concentrations in Test Houses*
Cliff I. Davidson and J.E. Borrazzo,
Carnegie - Mellon University

11:00 a.m. Additional Presentations
and
Open Discussion

12:15 p.m. LUNCH

SESSION II.

CHARACTERIZATION OF EMISSIONS FROM BUILDING MATERIALS, BUILDING OCCUPANTS AND CONSUMER PRODUCTS: LABORATORY STUDIES

Chair: Lars Molhave,
University of Aarhus, Denmark

1:30 p.m. *Considerations in Evaluating Emissions from Consumer Products*
John R. Girman, A.T. Hodgson and M.L. Wind,
Lawrence Berkeley Laboratory

2:00 p.m. *Environmental Chamber Test Methodology for Organic Vapors from Solid Emission Sources: A Formaldehyde Experience*
Thomas G. Matthews,
Oak Ridge National Laboratory

2:30 p.m. *Screening Protocols for Characterization of Emissions from Potential Candidates for Chamber Evaluation of Indoor Air Pollution Sources*
Leonard H. Nelms, R.G. Merrill, R.F. Martz and R.S. Stelber,
Acurex Corp.

3:00 p.m. Refreshment Break

3:15 p.m. *Procedure for Testing Materials in Small Chambers*
David C. Sanchez and M. Mason,
U.S. EPA (AEERL)

3:45 p.m. *Sensory Characterization of Environmental Tobacco Smoke*
William S. Cain,
John B. Pierce Fndn. Lab. & Yale University

4:15 Additional Presentations
and
Open Discussion

5:15 p.m. RECESS

TUESDAY, MAY 14

SESSION III.
CHARACTERIZATION OF SOURCES AND EMISSIONS IN FIELD STUDIES

Chair: David Grimsrud,
Lawrence Berkeley Laboratory

8:30 a.m. *Methodology for Relating Combustion Sources and Their Use to Residential Air Contaminant Levels in Field Studies*
Brian P. Leaderer, R.T. Zagraniski, M. Berwick and J.A.J. Stolwijk,
John B. Pierce Fndn. Lab. & Yale University

9:00 a.m. *Methodology for Relating Residential NO_2 Levels to Combustion Source Use*
David P. Harlos and J. Spengler,
Harvard University School of Public Health

9:30 a.m. *Field Monitoring Design Considerations for Assessing Indoor Exposures to Combustion Pollutants*
Gregory W. Traynor,
Lawrence Berkeley Laboratory

10:00 a.m. Refreshment Break

10:15 a.m. *Assessing Sources of Volatile Organic Compounds in Homes, Buildings, Building Materials and Consumer Products*
Lance A. Wallace, E. Pellizzari, B. Leaderer, D. Hartwell, K. Perritt, H. Zelon and L. Sheldon
U.S. EPA (EMSL)

10:45 a.m. *Methodologies for Evaluating Sources of VOC in Homes*
Bernd Seifert and D. Ullrich,
Institute for Water, Soil and Air Hygiene, Berlin, W. Germany

11:15 a.m. Additional Presentations
and
Open Discussion

12:15 p.m. LUNCH

SESSION IV.
MODELING OF SOURCE EMISSIONS

Chair: Jan A.J. Stolwijk,
Yale University & John B. Pierce Fndn. Lab.

1:30 p.m. *Indoor Source-Apportionment Modeling*
Ken Sexton and S.B. Hayward,
Health Effects Institute, Cambridge, Ma.

2:00 p.m. *Models for Estimating Organic Emissions from Building Materials*
Alan R. Hawthorne and T.G. Matthews
Oak Ridge National Laboratory

2:30 p.m. *Models and Statistical Methods for Gaseous Emission Testing of Static Sources in Well-Mixed Chambers*
James E. Dunn,
University of Arkansas

3:00 p.m. Refreshment Break

3:15 p.m. *Statistical Procedures for Conducting Multistage Field Studies*
Tyler D. Hartwell and R. Whitmore,
Research Triangle Institute

3:45 p.m. *Understanding the Origin of Radon Indoors - Building a Predictive Capability*
Richard G. Sextro,
Lawrence Berkeley Laboratory

4:15 p.m. *Design Strategy of an Indoor Air Pollutant Emissions Data File - - a Status Report*
Joseph E. Sickles, Y.S. Crume, R.L. Chessin, G. Johnson, M. Samfield and N. Yunt
Research Triangle Institute

4:45 p.m. Additional Presentations
and
Open to Discussion

5:30-7:00 p.m. RECEPTION - Poolside

WEDNESDAY, MAY 15

SESSION V.
SAMPLING AND ANALYSIS: CHAMBER AND FIELD STUDIES

Chair: Helmut Knoeppel,
Joint Research Center, ISPRA, Italy

8:30 a.m. *Bioassay Methods for Source Evaluation*
Joellen Lewtas,
U.S. EPA (HERL)

9:00 a.m. *Methodology for VOC Sampling and Analysis of Emissions from Combustion Sources*
William Gutknecht,
Research Triangle Institute

9:30 a.m. Refreshment Break

9:45 *Methodology for VOC Sampling and Analysis Used During Field Monitoring and Emission Rate Studies*
Linda Sheldon, J. Sickles, K. Thomas, J. Keever, D. Whitaker
Research Triangle Institute

10:15 a.m. *Sampling and Analysis of Biological Aerosols*
Harriet A. Burge and W.R. Solomon,
University of Michigan

10:45 a.m. Additional Presentations
and
Open Discussion

12:00 noon LUNCH

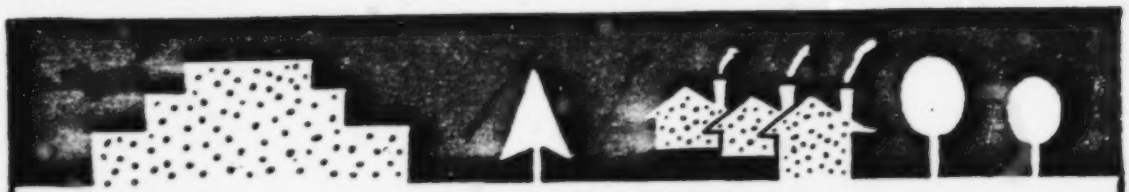
SESSION VI.
SUMMARY OF CONFERENCE FINDINGS - A PANEL DISCUSSION

Chair: Brian P. Leaderer

1:00 p.m. Panel: Session Chairmen
Gene Tucker
Lars Mølhave
David Grimsrud
Jan A.J. Stolwijk
Helmut Knoeppel

2:30 p.m. CLOSING REMARKS
Brian P. Leaderer

Abstracts



CHARACTERIZATION OF CONTAMINANT EMISSIONS FROM INDOOR SOURCES

May 13-15, 1985

Chapel Hill, North Carolina

Sponsors:

The Air and Energy Engineering Research Laboratory of the U.S. Environmental Protection Agency

The Electric Power Research Institute

The Gas Research Institute

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SESSION I

CHARACTERIZATION OF EMISSIONS FROM COMBUSTION SOURCES IN THE LABORATORY SETTING

CHAIR: GENE TUCKER

EMISSIONS FROM UNVENTED COMBUSTION SOURCES

Warren K. Porter, Jr.*

Directorate for Health Sciences
U.S. Consumer Product Safety Commission
Washington, D.C. 20207

The use of small, unvented space heaters as primary means of heating houses has been restricted largely to areas of mild climate because of the low to moderate heat output from these appliances. The increasing cost of energy which has occurred in recent years has led homeowners in colder climates to install insulation, storm windows and utilize other means of tightening and reducing the natural infiltration of air into their residences. The availability of promotion of portable kerosene space heaters has allowed the homeowner to more or less conveniently supply heat to maintain individual rooms at a comfortable temperature while the remainder of the house is maintained at lower temperatures by the central heating system. In order to assess the potential for adverse health effects resulting from the expected use of these appliances, perhaps daily, for periods of six hours of longer, investigations of emissions of carbon monoxide (CO), nitrogen oxides (NO_x) and sulfur dioxide (SO_2) have been performed.

Early studies of No_x by the Japanese have been substantially confirmed by other investigators. These studies, performed in both laboratory and field settings, have shown a remarkable consistency between investigators for emission rates for NO_x, SO_2, and CO. During these studies with kerosene and unvented gas space heaters it has become apparent that the emission rates are dependent not only on fuel type, but, with some appliances, also on the adjustment of the primary air/fuel ratio, length of time the burner has been operating, and either over- or under-firing of the burner.

Initial studies determined that particles resulting from the operation of these appliances did not result in inordinately high masses of materials; however, the particles were found to be both fine and numerous. Little work has been reported on the composition of the organic matter which make up the particles. Studies in progress are attempting to determine if the particles contain substantial amounts of polycyclic organic matter. Methods of analysis, developed during investigations of wood-fired stoves, permit collection of not only particle bound but vapor phase POMs as well.

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* The author is employed by the Consumer Product Safety Commission. Since this paper was written in his official capacity, it is in the public domain and may be freely copied or reprinted. The opinions expressed by the author do not necessarily represent those of the Commission.

EMISSION RATES OF INORGANIC AND ORGANIC AIR CONSTITUENTS FROM UNVENTED INDOOR COMBUSTION SOURCES

Demetrios J. Moschandreas

IIT Research Institute
10 West 35th Street
Chicago, Illinois 60616

Pollutant emissions from unvented combustion sources in indoor environments generate indoor air pollution. Measurements of emission rates from such sources are required to determine the source contribution and character of indoor air quality and techniques to mitigate undesired concentrations of pollutants. Emission rates have been measured in both field studies and in the laboratory. One of two methods is generally used: (1) The Direct Method: emitted effluents are directed to one sampling location, stoichiometric principles are used to estimate the emission rates; and (2) The Mass Balance Method: emitted effluents are allowed to disperse throughout the experimental chamber; all relevant parameters are measured and used as inputs in a mass balance equation which is solved for the emission rate value. These two generic methods, or variations, have been applied to determine pollutant emission rates from kerosene space heaters, and from unvented gas appliances such as range top burners, ovens, and gas space heaters. Most studies focus on the emission rates of inorganic air constituents (NO, NO_2, CO, and a few others). Emission rates for organic air constituents, including VOCs, PAH, and the like have been studied only by few researchers.

This paper elaborates on the two methods of measurement, summarizes available results, and assesses the present state-of-the-art. The emission rates of inorganic air constituents from unvented combustion sources are well quantified, but vary widely as a function of source type and condition of the source. The emission rates of organic air constituents from such sources are not well understood and may depend on the method of measurement and analysis. Research is needed to establish the distribution of emission rates from unvented combustion sources of the U.S. housing stock. Research is also warranted to determine the validity of the measured low emission rates of organic air constituents.

MEASURING ENVIRONMENTAL EMISSIONS FROM TOBACCO COMBUSTION*

Michael R. Guerin, C. E. Higgins, S. K. Holladay, and R. A. Jenkins

Organic Chemistry Section, Analytical Chemistry Division,
Oak Ridge National Laboratory, Oak Ridge, TN 37831

The tobacco-derived environmental emission of primary concern is the smoke issuing from the product between puffs, i.e., the sidestream smoke. Studies of mainstream smoke have demonstrated a large dependence of quantitative delivery and of chemical composition on subtle changes in product design or analytical method. This has led to detailed standardization of product handling and of methods for sampling and analysis in order to generate interpretable results. Sidestream smoke has not been given similar attention and this may account for conflicting reports concerning the particulate matter/vapor phase distributions of SS nicotine and SS HCN and the SS/MS ratios of cigarette smoke acids.

Variables which affect static burn rate (e.g., moisture content, air flow rate over the fire cone, and nitrate additives) have a major influence on cigarette SS emission factors. SS emission compounds derived predominantly from single precursors (e.g., NO from nitrate content and volatile pyridines from nicotine alkaloids) are highly influenced by the tobacco blend and additives employed. In contrast to MS analysis, SS samples may be taken at almost any point in the tobacco rod and confidently extrapolated to whole cigarette emission. It is found that reliable measures of SS emissions do require that the cigarette be puffed and not merely allowed to smolder.

Commonly used devices for determining SS composition are described and resulting emission factors are tabulated. Vapor phase chromatographic profiles and measures of TPM, H_2O, nicotine, tar, and CO are used to illustrate the importance of various experimental parameters on SS emission factors. Chamber studies illustrate that the vapor phase composition of diluted SS is well represented by freshly generated SS.

* Research sponsored by the National Cancer Institute under Interagency Agreement DOE No. 40-485-74, (NIH) NCI No. Yol-CP-30508 under Martin Marietta Energy Systems, Inc., contract DE-AC05-840R21400 with the U.S. Department of Energy.

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THE USE OF LABORATORY-DERIVED EMISSION FACTORS FOR PREDICTING POLLUTANT CONCENTRATIONS IN TEST HOUSES

Cliff I. Davidson and John E. Borrazzo

Department of Civil Engineering and Engineering & Public Policy
Carnegie-Mellon University
Pittsburgh, PA 15213

Several investigators have studied pollutant emissions from indoor sources. Particular efforts have been devoted to unvented stoves and space heaters involving combustion of natural gas or kerosene. These studies have focused on the emissions of CO, NO, NO_2, and other pollutants under controlled laboratory conditions using sampling hoods or chambers. Although such research has produced a wealth of data on emission factors for household appliances, the extent to which these data can be applied to occupied houses has not been investigated in detail.

The present study critically examines the viability of published emission factor data for use in predicting pollutant concentrations in residences. CO, NO, and NO_2 are of primary interest, due to the sizeable database for these species.

Potential problems with the use of emission factor data can be categorized into three topic areas. First, sampling and analytic errors may lead to inaccurate pollutant concentration data for the hood or chamber, resulting in erroneous emission factor estimates for conditions during the tests. Second, the process of conducting the tests may alter characteristics of the appliance so that emissions during testing are different from those during normal appliance use. Changes in combustion characteristics, caused by airflow patterns introduced by the sampling apparatus or by changes in relative humidity, are of particular importance. Third, appliance use patterns during the tests may be different from those during normal use. For example, many emissions tests have been conducted during steady-state operation of appliances; normal use, however, may entail brief periods of operation with substantially different emission factors.

Each of these topic areas is considered in detail. Emissions data from a gas-fired stove in a test house in Pittsburgh, as well as literature data, are examined to explore possible problems. Critical gaps in our understanding of these problems are identified, and future research topics are suggested.

SESSION II

CHARACTERIZATION OF EMISSIONS FROM BUILDING MATERIALS, BUILDING OCCUPANTS AND CONSUMER PRODUCTS: LABORATORY STUDIES

CHAIR: LARS MØLHAVE

CONSIDERATIONS IN EVALUATING EMISSIONS FROM CONSUMER PRODUCTS

John R. Girman, Alfred T. Hodgson
Indoor Air Quality Program
Lawrence Berkeley Laboratory
Berkeley, CA 94720

and

Marilyn L. Wind
Division of Health Effects
U.S. Consumer Products Safety Commission
Bethesda, MD 20207

While several indoor air quality studies suggest consumer products can be significant sources of volatile organic compounds (VOC), until recently characterizing emissions from consumer products has received relatively little attention. This is in strong contrast to the characterization of emissions from combustion appliances and building materials where numerous chamber studies have been conducted. Many considerations that must be addressed in protocols for chamber studies of consumer product emissions are similar to those addressed in these other types of indoor air quality studies. These similarities will be discussed briefly and include: defining the potential health hazard; establishing study goals; assessing instrument and chamber capabilities; pretesting and establishing the experimental procedures; and assessing quality assurance and control needs. However, there are additional considerations that must be addressed that are unique to chamber studies of consumer product emissions. These unique considerations in protocol development will be discussed in detail with reference to an ongoing study of consumer products. If possible, chamber VOC concentrations for specific conditions can be estimated with sufficient accuracy to simplify specification of analytical instruments and sampling design. However, the form of the product (e.g., liquid, aerosol, or paste) and the related consumer usage pattern can have great impacts on VOC concentrations and, therefore, must be considered carefully in the design of the study. Local air flows near the applied product can also have an impact, not only directly, by sweeping away VOC but indirectly as well, through cooling of the product due to rapid solvent evaporation. In addition, the issue of personal exposure of the product user versus the average area concentration in the chamber resulting from product use must be considered in terms of concentration gradients established. The challenge of incorporating results into predictive models that adequately treat the effect of different usage patterns will be discussed. Finally, post-study considerations, such as exploring issues previously ignored due to limited resources, exploring new issues discovered in the study, studying similar products, and validating models through extension into field studies will be summarized.

This work was supported by the Assistant Secretary for COnservation and Renewable Energy, Office of Building Energy Research and Development, Buildings Systems Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098 and by the Directorate of Health Sciences of the U.S. Consumer Product Safety Commission under Contract No. CPSC-IAG-84-1171.

ENVIRONMENTAL CHAMBER TEST METHODOLOGY FOR ORGANIC VAPORS FROM SOLID EMISSION SOURCES: A FORMALDEHYDE EXPERIENCE

Thomas G. Matthews

Measurement Applications Group
Health and Safety Research Division
Oak Ridge National Laboratory

Laboratory chambers provide a powerful measurement tool for evaluation of organic emission rates from consumer and construction products under a variety of environmental exposures that partially simulate real-world conditions. The physical design, experimental protocol, and environmental test conditions that are chosen for chamber measurements are inextricably linked to the overall project plan for the characterization of organic emissions from solid emission sources. Such a plan describes a complex series of decision points concerning (1) the selection of test materials, (2) the design of environmental chamber test methodology, (3) data analysis and evaluation with existing physical or empirical theory, and (4) validation of data and theory under real world scenarios.

The development of an environmental chamber test methodology can be divided in three basic components including (1) the physical design of the test chamber apparatus, (2) the experimental protocol for materials testing, and (3) the analytical method for measurement of organic emissions. The physical design should provide uniform temperature, relative humidity, and organic vapor concentration levels throughout the inside of the chamber. The chamber should be operable at temperature and relative humidity levels consistent with indoor product exposures. The range of air flow rates should be selected to achieve organic vapor concentrations consistent with indoor levels using reasonable product loadings inside the chamber. The experimental protocol should specify procedures for test sample preparation, conditioning, and testing under controlled environmental conditions. The analytical methodology should provide the necessary sensitivity and reproducibility to accurately determine organic vapor concentrations inside the chamber.

An extensive environmental chamber measurements program (on formaldehyde [CH_2O] emissions from pressed-wood and insulation products) has been conducted at Oak Ridge National Laboratory. These chamber studies were part of projects that included (1) surveys of CH_2O emissions from U.S. manufactured products, (2) chamber measurements of selected products under a broad range of environmental conditions, (3) modeling of product emissions and impact on indoor concentrations, and (4) validation studies in large scale chambers and unoccupied research homes. Detailed procedures for product handling during preparation, conditioning, and measurement periods, plus calibration and measurement procedures for CH_2O, were developed. This experience should provide useful input in the development of environmental chamber test protocols for solid organic emissions sources commonly found in indoor environments.

* Research sponsored by the U.S. Environmental Protection Agency under Interagency Agreement EPA-IAG-40-1473-84 and the Office of Health and Environmental Research, U.S. Department of Energy, under contract DE-AC05-840R21400 with the Martin Marietta Energy Systems, Inc.

SCREENING METHODS FOR THE IDENTIFICATION OF ORGANIC EMISSIONS FROM INDOOR AIR POLLUTION SOURCES

Raymond G. Merrill, Raymond S. Steiber
U.S. Environmental Protection Agency,
Air and Energy Engineering Research Laboratory
Research Triangle Park, North Carolina 27711

and

Robert F. Martz and Leonard H. Nelms
Acurex Corporation, Energy and Environmental Division
P.O. Box 13109
Research Triangle Park, North Crolina 27709

Prior screening of materials that are to be evaluated in the emissions test chamber is necessary to devlop on-line gas chromatographic methods that will be used in the testing program. This evaluation and dynamic methods similar to the "purge-and trap" procedure used for determination of volatile organic compounds in water samples. These are methods of sampling that simulate the chamber conditions on a small scale, while allowing emissions to be collected and analyzed. During the course of the evaluation, the suite of chemical compounds that is emitted from a material to be tested in the chamber is used to select a gas chromatographic column and develop a set of operating conditions that will permit the rapid and reliable separation of these materials during testing. The resulting chromatographic procedure is then used in the qualitative identification of these compounds by gas chromatography/mass spectrometry. After identification of the compounds, or, alternately, their chemical classes, representative members of the group are selected for use as calibration standards for the on-line chromatograph during the actual testing program. The standards selected are adequate to allow, in most cases, either quantitative or semi-quantitative calculation of the amount of each material present in the chamber exhaust gas for any chemical compounds having peak resolution sufficiently adequate to permit computation of peak areas. The use of response curves for the chemical classes allows subsequent recalculation of precise amounts for each compound by comparison of relative response factors from subsequent experiments to those obtained from the chamber testing program.

METHODS AND RESULTS OF CHARACTERIZATION OF ORGANIC EMISSIONS FROM AN INDOOR MATERIAL

David C. Sanchez
Air and Energy Engineering Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

and

Mark Mason and Carolyn Norris
Acurex Corporation
Research Triangle Park, North Carolina 27711

Several investigators have measured dozens of organic compounds in the air in office buildings and residences at concentrations that substantially exceed both (a) the concentrations of these compounds outdoors, and (b) maximum concentrations allowed by EPA standards for regulated pollutants such as SO_2, NO_2, and particles. Many of these compounds are thought to be coming from indoor materials via evaporation or "outgassing". This paper will focus on the procedures employed by the Air and Energy Engineering Research Laboratory to contribute to the research community knowledge of organic emissions from indoor materials.

An emission test facility (ETFL) has been designed, fabricated and installed and is now operating at EPA's Environmental Reseach Center in Research Triangle Park, N.C. The facility has been designed to permit the conditioning and exposure of samples of indoor materials and products to controlled environmental (temperature, humidity, and ventilation) conditions. Initial mechanical (environmental control) and organic emissions recovery testing of the chamber has been conducted to evaluate the performance of the test facility in maintaining specific environmental conditions and in permitting recovery of organic emissions through the ETF.

Results in the form of test procedure guidance and quantitative chemical speciation of emissions from selected materials will be presented. Emphasis will be placed upon discussion of quality assurance and statistical evaluation of preliminary tests conducted at the ETF.

SENSORY CHARACTERIZATION OF ENVIRONMENTAL TOBACCO SMOKE

William S. Cain

John B. Pierce Foundation Laboratory and Yale University
290 Congress Avenue
New Haven, CT. 06519

Certain indoor contaminants can be characterized both physically and psychophysically. In the case of the contaminant tobacco smoke, a physical analysis reveals enormous complexity, namely more than two thousand individual constituents. Psychophysically, the contaminant is far less complex, but nevertheless hardly simple. Although the quality of tobacco smoke odor will vary with such factor as its age, its annoyance potential seems to derive mainly from its perceived intensity. A person who enters an area of smoking from an area of nonsmoking will immediately notice odor and may or may not find it objectionable. If the person remains in the space and if the smoking has produced 2 ppm or greater carbon monoxide, then he/she will also begin to notice gradually increasing irritation that may grow even for hours. Although odor may fade, eye irritation, nasal irritation, and throat irritation will increase in characteristic manner. Use of an electrostatic precipitator has some mitigating influence; irritation will come on more slowly and have less impact, although it will still be discernible eventually. Since the odor of environmental tobacco smoke is also affected by the use of a precipitator, it would appear that the particles per se make no clear contribution to irritation.

SESSION III

CHARACTERIZATION OF SOURCES AND EMISSIONS IN FIELD STUDIES

CHAIR: DAVID GRIMSRUD

METHODOLOGY FOR RELATING COMBUSTION SOURCES AND THEIR USE TO RESIDENTIAL AIR CONTAMINANT LEVELS IN FIELD STUDIES

Brian P. Leaderer, Rebecca T. Zagraniski*,
Marianne Berwick and Jan A.J. Stolwijk

The John B. Pierce Foundation Lab., New Haven, CT., and Dept. of Epidemiology and Public Health, Yale U. School of Medicine, New Haven, CT, 06519 and *New Jersey Dept. of Health Env. Health Program, Trenton, N.J. 08625

In a field study of 302 residences, the indoor air contaminant concentrations associated with the use of unvented kerosene space heaters and gas cooking stoves were measured. For each residence, two-week average NO_2 levels were recorded outdoors and in three rooms using diffusion-type passive monitors. Data were obtained on NO_2 sources, the level of use of these sources, and on building characteristics from an initial questionnaire, a bi-weekly telephone interview, daily diaries and from tax assessor records. A multivariate model for the collected field study data is used to relate the residential NO_2 levels measured to the source and source use parameters recorded. The methodology employed in the field study is evaluated in terms of a multivariate model which predicts variation in NO_2 level as a function of the existence and reported use of sources in the multivariate model. The levels of specification needed for other independent variables (infiltration, sink or removal rates, etc.) in the predictive model presented is discussed. Based upon this evaluation, recommendations are made for modifications in the methodology employed in this field study which would be useful in assessing indoor air contaminant levels in field studies on the basis of limited measurements and observations.

METHODOLOGY FOR RELATING RESIDENTIAL NO_2 LEVELS TO COMBUSTION SOURCE USE - (The Harvard Study)

David P. Harlos and John D. Spengler

Department of Environmental Science & Physiology
Harvard School of Public Health
665 Huntington Avenue
Boston, MA. 02115

Quantifying the effects of nitrogen dioxide exposure on human respiratory health to an epidemiologic setting has proven to be a difficult task. Modeling studies indicate that exposure misclassification may be a serious obstacle in identifying health impacts, a conclusion which is underscored by the difficulty in obtaining cost-effective, accurate personal exposure measurements among real populations. Modeling indoor residential NO_2 exposures is difficult since NO_2 dispersal is a dynamic process that produces horizontal and vertical concentration gradients in homes. This paper presents the results of a field survey of 50 homes in Albuquerque, New Mexico, occupied by non-smoking parents of newborn infants. We measured source use, average NO_2 concentrations and infant personal exposure in an attempt to obtain accurate NO_2 personal exposures for infants.

The 50 residences were selected from the extremes of the NO_2 distribution of a survey of 150 homes. The 50 homes were re-sampled with a variety of strategies using two types of diffusion samplers and one type of active NO_2 sampler. Infant personal NO_2 samples and T/A logs were also taken. Source strength was estimated from diffusion samplers placed over stove burners. A hierarchy of progressively detailed exposure estimates is constructed from environmental measurements and compared with personal NO_2 and modeled NO_2 exposure estimates.

FIELD MONITORING DESIGN CONSIDERATIONS FOR ASSESSING INDOOR EXPOSURES TO COMBUSTION POLLUTANTS

Gregory W. Traynor

Lawrence Berkeley Laboratory
Building Ventilation & Indoor Air Group
1 Cyclotron Road
Berkeley, CA. 94720

Laboratory and controlled-field studies of indoor air quality (IAQ) have characterized pollutant emission rates from combustion sources and have measured other key indoor air pollutant parameters such as air exchange rates and indoor reactivity rates for the houses investigated. In addition, several field studies have attempted to measure, with varying degrees of success, pollutant exposures, indoor air quality concentrations, and other IAQ parameters in large populations. To date, a well-defined strategy for assessing indoor exposures to combustion-related pollutants and factors that affect such exposures has not been developed in a comprehensive manner that would provide distributions of exposures to combustion pollutants and of factors that affect such exposures in large populations. Although some important IAQ factors such as unvented appliance pollutant emission rates can be partially characterized in laboratory studies, other factors such as appliance usage patterns cannot. This paper outlines the important parameters that affect combustion-generated indoor air pollution concentrations and exposures, delineates various strategies to quantify parameter distributions, and mentions considerations in choosing appropriate strategies.

ASSESSING SOURCES OF VOLATILE ORGANIC COMPOUNDS IN HOMES, BUILDINGS, BUILDING MATERIALS, AND CONSUMER PRODUCTS

Lance A. Wallace*, E. Pellizzari, B. Leaderer, T. Hartwell, K. Perritt, H. Zelon, and L. Sheldon

Harvard University School of Public Health
665 Huntington Avenue
Boston, MA 02115

EPA's TEAM Study of personal exposure to volatile organic compounds (VOC) in air and drinking water of 350 New Jersey residents resulted in the identification of a number of possible sources encountered in peoples' normal daily activities and in their homes. A followup EPA study of public access buildings implicated other potential sources of exposure. To learn more about these potential sources, fifteen building materials and common consumer products were analyzed semiquantitatively using a headspace technique to detect organic emissions. About 50-100 organic compounds were detected off-gassing from each material. Five mixtures of materials were then chosen for detailed study: paint on sheetrock; carpet and carpet glue: wallpaper and fixer: cleansers and a spray pesticide: and cigarettes. The materials were applied in the normal manner, allowed to age one week (except for the cleansers and cigarettes, which were used normally during the monitoring period), and placed in an environmentally controlled chamber. Organic vapors were collected on Tenax-GC over a 4-hour period. Emission rates and chamber concentrations were calculated for 17 target chemicals chosen for their toxic, carcinogenic, or mutagenic properties. Of the 17, only three target chemicals were not found in the four non-tobacco categories. Elevated concentrations of chloroform, carbon tetrachloride, 1,1,1-trichloroethane, decane, undecane, p-dichlorobenzene, 1,2-dichloroethane, and styrene were observed in the four non-tobacco categories. Smoking appeared to be an important source of exposure to benzene and styrene. A number of other activities were identified as potentially important sources of exposure to the target compounds.

METHODOLOGIES FOR EVALUATING SOURCES OF VOC IN HOMES

Bernd Seifert and D. Ullrich

Institute for Water, Soil and Air Hygiene
of the Federal Health Office, Berlin, FRG

The importance of research to enlarge our knowledge about the occurrence of volatile organic chemicals (VOC) in indoor air has been recognized during the last few years and respective recommendations for work to be done in this field have been made recently (WHO Saltsjöbaden meeting on Indoor Air Quality, August 1984). Although some good and meaningful results of measurements of VOC concentrations in enclosed spaces have been published (cf. TEAM study, Proc. Indoor Air '84), the respective work has not always been carried out under conditions which would permit a straightforward evaluation of the different sources of VOC in homes.

VOC emitting sources may be classified into two principal categories: (A) Sources with a continuous emission, and (B) Sources with an intermittent emission. Depending on the type of a source, there will be different approaches on how to characterize its emission adequately.

For sources of type A, e.g., construction materials or pieces of furniture made of chip-board, the dominant factors causing a variation in the VOC concentration in the air of the respective room will be the ventilation rate, the temperature and perhaps the humidity. The influence of the point-in-time and the duration of sampling can be neglected provided the sampling protocol takes these dominant factors into account.

In contrast to this, VOC emissions from type B sources, e.g., spray cans, call for an evaluation using a sampling strategy which takes into account the much greater time-dependency rather than changes in ventilation rate, temperature and/or humidity.

Examples for the two cases are presented and the results of respective measurements are discussed. Included in the discussion is the possibility of evaluating the contribution of different sources of VOC to the measured VOC concentration by means of questionnaires.

SESSION IV

MODELING OF SOURCE EMISSIONS

CHAIR: JAN A. J. STOLWIJK

INDOOR SOURCE-APPORTIONMENT MODELING

Ken Sexton
Health Effects Institute
215 First Street
Cambridge, Massachusetts 02142

and

Steven B. Hayward
Indoor Air Quality Program
California Department of Health Services
2151 Berkeley Way
Berkeley, California 94704

An understanding of the relative contributions of important emission sources to human exposures is a prerequisite for the design and implementation of effective control strategies. In the past, societal efforts to control air pollution have focused almost exclusively on the outdoor (ambient) environment, and a great deal of time and money has been spent to limit airborne discharges from mobile and stationary sources. Yet, it is now recognized that exposures to elevated pollutant concentrations often occur as a result of indoor rather than outdoor sources. While the major indoor sources have been identified, their relative impact on indoor air quality is not well defined. Application of existing source-apportionment models to nonindustrial indoor environments offers the possibility of distinguishing between indoor and outdoor emissions as well as among indoor sources themselves. However, the assumptions and data requirements of available models, major determinants of indoor pollutant concentrations, and diversity of indoor settings must be taken into account before the feasibility and suitability of source-apportionment methods can be assessed adequately. This paper examines the relative merits of dispersion and receptor models for indoor source apportionment and reviews the need for emission characterization studies. Emphasis is placed on the justification for indoor source-apportionment modeling and the role of chamber experiments in establishing critical emission profiles.

MODELS FOR ESTIMATING ORGANIC EMISSIONS FROM BUILDING MATERIALS*

Alan R. Hawthorne and Thomas G. Matthews

Measurement Applications Group
Health and Safety Research Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831

One important source of chronic exposure to low levels of organic compounds in the indoor environment is emissions from building materials. Because removal of offending products may be costly and/or impractical, it is important that the emissions of organic pollutants be understood prior to incorporation of these materials into buildings. Once the organic pollutants of concern are identified, based on potential health effects and emissions from building material, it is necessary that an emission model be developed to predict the behavior of the emission rate under various indoor conditions. Important factors that may have a significant impact on the emission rate of an organic vapor include product aging, product exposure to various temperatures and humidities, concentration of the organic vapor in the indoor environment, and the product's characteristic source strength at standard test conditions. The emission models should be compatible with indoor pollutant concentration models baded on mass balance considerations. Ideally, the models should have a phenemonological basis that will allow a sensitivity analysis to identify the important factors that affect emission rates. The emission rate models would then be helpful in modifying those factors that are most effective in reducing organic emissions and in providing effective mitigation measures when necessary. The most studied of the volatile organic compounds, formaldehyde, will be used to illustrate model development for organic emissions from various building materials, including pressed wood products, urea formaldehyde foam insulation, fiberglass insulation, carpet, and carpet cushioning.

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MODELS AND STATISTICAL METHODS FOR GASEOUS EMISSION TESTING OF FINITE SOURCES IN WELL-MIXED CHAMBERS *

James E. Dunn

Department of Mathematical Sciences,
University of Arkansas
Fayetteville, AR 72701

A review of current literature on controlled tests of gaseous emissions from indoor building materials leaves one frustrated for the lack of a precise definition of emission rate. Commonly, an estimate is reported which reflects average emission units per unit time over some specified interval. However, this presumes a steady state condition, which appears to be an untested assumption. As an alternative, it is proposed that emission be described in terms of a physically meaningful family of models, indexed by one or more unknown parameters which must be estimated from the test data. The advantages are (1) a well-fitting model can be used for interpolation inside and limited extrapolation outside the region of actual test conditions, and (2) the parameters themselves can be indexed with respect to environmental factors such as temperature, humidity, loading ratio, etc.

Two such families of models are proposed for the concentration in a well-mixed test chamber. One is an o.d.e. solution for thin film sources such as carpet glue, stains and varnishes, etc.; the other is a p.d.e. solution of the diffusion equation for deep sources such as particle board, plywood, etc. Neither family exhibits a steady state condition. Model fitting and interpretation are demonstrated, both for concentration data based on continuous, online analysis, and in integrated form for those cases where emissions must be trapped over a finite period before initiating on analysis. Finally, use of efficient designs, such as graeco-latin squares, is explored as a basis for controlled experiments involving combinations of many factors. Insight into the effects of these factors is obtained by using estimates of the model parameters as data in the subsequent analysis of variance.

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STATISTICAL PROCEDURES FOR CONDUCTING MULTISTAGE FIELD STUDIES

Tyler D. Hartwell and Roy Whitmore

Research Triangle Institute

In order to make valid statistical inferences to a target population using populations sampled during a field study it is necessary to employ probability sampling methods. Several procedures for properly selecting individuals or households to participate in a field study will be discussed. In particular, efficient methods for oversampling individuals or households with selected characteristics (e.g., various source characteristics such as presence of gas stoves or demographic characteristics, such as a particular age group) to participate will be illustrated. These methods involve multistage samples with an initial stage of screening to determine household and individual characteristics before the final sample is drawn. The methods include choosing and listing of households in selected geographic areas; field-screening of households; the use of geographical classified telephone directory listings, or random digit dialing for telephone screening and the use of specialty lists such as those from electric utilities to obtain telephone numbers and addresses for screening. All of these procedures have been used in various combinations for field studies but they are efficient for different types of studies. A brief summary of when each procedure is appropriate will also be presented.

UNDERSTANDING THE ORIGIN OF RADON INDOORS -- BUILDING A PREDICTIVE CAPABILITY

Richard G. Sextro

Building Ventilation and Indoor Air Quality Program
Lawrence Berkeley Laboratory
University of California, Berkeley
Berkeley, CA. 94720

Indoor radon concentrations one to two orders of magnitude higher than the U.S. average of ~40 Bq m^{-3} (~1 pCi l^{-1}) are not uncommon, and concentrations greater than 4000 Bq m^{-3} have been observed in houses in areas with no known artificially-enhanced radon sources. In general, source categories for indoor radon are well known: soil, domestic water, building materials, and outdoor air. The latter two source categories have generally been found to have low radon source strengths. Domestic water supplies also typically contribute little to airborne radon concentrations, although in certain localities water has been identified as a significant source. Soil, on the other hand, is thought to be a major source of indoor radon, either through diffusive (usually a minor component) or bulk flow of soil gas. While soil gas flow into residences has been demonstrated, no general understanding of the important factors affecting the source strength of radon from soil has yet emerged. Preliminary work in this area has identified a number of likely issues, including the concentration of radium in the soil, the emanating fraction, soil type, soil moisture content, and other factors that would influence soil permeability and soil gas transport. A predictive capability is needed that would help identify geographical areas having the potential for high indoor concentrations. The development of such a capability will require additional scientific study of the soil-related factors discussed above, along with an exploration of existing data bases that might provide indicators of radon concentrations. In addition to soil-specific factors, an examination of the coupling between the soil and the living space provided by various building types and substructures is needed, and the role of local meteorology - rainfall, wind loading, barometric pressure changes, and building thermal loads - must be assessed.

DESIGN STRATEGY OF AN INDOOR AIR POLLUTANT EMISSIONS DATA FILE -- A STATUS REPORT

Joseph F. Sickles, Y.S. Crume, R.L. Chessin
Research Triangle Institute
Research Triangle Park, NC 27709

G. Johnson and M. Samfield
EPA
Research Triangle Park, NC 27711

N. Young
Acurex Corp
Research Triangle Park, NC 27709

The objective of this work is to develop a conceptual design for a computerized data base to archive existing emission factors for indoor sources of air pollutants. Results published from 1979-1984 are considered, with emphasis on building materials and combustion sources. A major goal is to make emissions factors readily accessible to users with a wide range of interest.

The approach involves progressing through three levels of specificity from general to specific. The first level includes descriptions of the source category, the test facility, and the reference where the results were published. The second level involves a detailed description of the test. The third and most specific level includes a detailed description of each measurement involved in the determination of the resulting emissions factor.

The above approach provides a framework that is similar to that employed by EPA's Environmental Assessment Data System (EADS). EADS was designed to act as a comprehensive repository for multi-media environmental sampling and analysis data, to provide a standardized protocol for reporting data, and to document the quality of the reported data. Currently EADS consists of four data bases that archive emission data on fine particles, gaseous pollutants, liquid effluents, and solid discharges. Since the framework and goals employed by EADS are similar to those for the current effort, it was decided to modify EADS to accomodate an indoor air pollutant emissions data base.

The status of the current effort is summarized as follows: approximately 60 articles have been identified, reviewed, and abstracted for inclusion in the data base. A framework for the data base has been designed. An existing computerized system of data bases (EADS) is being modified to be used as an indoor air pollutant emission data base.

SESSION V

SAMPLING AND ANALYSIS: CHAMBER AND FIELD STUDIES

CHAIR: HELMUT KNÖPPEL

BIOASSAY METHODS FOR COMBUSTION SOURCE EVALUATION OF INDOOR AIR

Joellen Lewtas, Sumio Goto, Katherine Williams, Randall Morin, Judy Mumford and Larry Claxton
U.S. EPA, Health Effects Research Laboratory, Genetic Bioassay Branch (MD 68), Research Triangle Park, NC 27711

Short-term genetic bioassays have been extensively used to characterize and assess the potential cancer risk from combustion sources. In order to apply these methods to indoor air studies, we found it necessary to develop a micro-mutagenesis bioassay method. We have modified and optimized the Salmonella typhimurium (TM 677) forward mutation assay originally developed by Skopek and Thilley in order to provide a sensitive bioassay to quantitate the mutagenicity in microgram quantities of indoor air particulate extracts. This micro-forward mutation assay has been compared to the standard reverse mutation assay developed by Ames et al. Source characterization chamber studies are being conducted on side-stream cigarette smoke, kerosene heaters and other combustion sources.

A pilot field study has been conducted in collaboration with EPA's Environmental Monitoring Systems Laboratory and Batelle Columbus Laboratories. Particulate matter and semi-volatiles were collected indoors using a medium volume sampler. Organic extracts of the particles have been bioassayed in the micro-forward mutation assay. It was possible to quantitate the mutagenicity in terms of mutation frequency/cubic meter of air sampled. The combustion source variables explored in this study included gas heaters and stoves, fireplaces in use and smoking. The results of this study and implications for the design of future studies will be discussed.

METHODOLOGY FOR VOC SAMPLING AND ANALYSIS OF EMISSIONS FROM COMBUSTION SOURCES

William F. Gutknecht

Research Triangle Institute
Research Triangle Park, N.C. 27709

Volatile organic compounds are emitted from a variety of indoor combustion sources. These sources include fireplaces, woodstoves, kerosene heaters and gas ranges. Sampling the emissions from these various sources can be performed in a variety of ways. Included are: (1) direct probe sampling of the combustion plume; (2) having the source in a flow-through chamber and sampling the air exhausted from the chamber; and (3) collection using personal samplers worn by individuals who work/live in close proximity to these sources. The devices or media used for collection will be determined to some extent by the expected levels. Samples from high level emitters such as fireplaces can be collected in Tedlar bags or canisters. Low-level emitters such as well-tuned space heaters or gas ranges will need to be sampled with sorbents such as charcoal, Tenax or XAD in order to collect sufficient quantities of material for analysis. It should be noted that the operational parameters of the sources, such as type of fuel used and the amount of air provided, affect significantly the levels of emissions found. The analyses of these samples are performed using techniques used for determination of volatile organic compounds collected from most other sources, including principally gas chromatography and/or gas chromatography/mass spectrometry. Identification is performed most efficiently using gas chromatography/mass spectrometry, although identification can be achieved through comparison of gas chromatographic retention times of standards and unknowns measured using state-of-the-art capillary columns. Quantification is most efficiently performed using capillary column gas chromatography.

METHODOLOGY FOR VOC SAMPLING AND ANALYSIS USED DURING FIELD MONITORING AND EMISSION RATE STUDIES

Linda Sheldon, J. Sickles, K. Thomas, J. Keever, D. Whitaker

Analytical and Chemical Sciences
Research Triangle Institute
P.O. Box 12194
Research Triangle Park, NC 27709

Sorbent collection/GC-MS or GC/FID techniques have been applied to the identification and quantitation of volatile organics during indoor air field studies and emission rate studies. The analytical methodology used at Research Triangle Institute employs Tenax GC as the sorbent material. Samples are collected by pulling air through the Tenax cartridges. The exposed cartridges are then analyzed by thermal desorption/capillary gas chromatography/mass spectrometry. Organic compounds are quantitated using response factors generated relative to bromopentafluorobenzene as a quantitation standard. Response factors are generated from liquid injections of volatile organics.

For field monitoring studies, samples are collected in triplicate at each sampling location using flow rates of 10, 20 and 30 ml/min for 12-hour periods. For each building studied, samples are collected over three days at three indoor and one outdoor location.

Emission rate studies are performed using small (~5l) glass chambers designed to minimize reaction of the target chemicals with the chamber materials and to allow thorough mixing, ventilation and representative sample acquisition. Chambers are ventilated with purified air, humidified to a desired level at a constant temperature. Collection of air samples is conducted under equilibrium conditions. Headspace scouting experiments are used to select test materials, target volatiles, collection times, and mass of material used. A mass balance equation is applied to calculate emission rates.

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SAMPLING AND ANALYSIS OF BIOLOGICAL AEROSOLS

Harriet A. Burge, and William R. Solomon

University of Michigan Medical Center
Ann Arbor, MI 48109

Sampling for biological aerosols includes both air sampling and source sampling. Efficiency of air sampling depends on particle shape and size, and wind speed and/or turbulence. Gravity or fall-out sampling methods (not recommended) are strongly influenced by both factors. With small particles and any air movement, gravity sampling is grossly inefficient. Volumetric sampling devices are of two types: rotating impactors and suction devices. Impactors are relatively insensitive to wind speed and are most efficient for larger particles (> 20μm). Suction devices are extremely sensitive to wind speed and direction, and their efficiency increases with decreasing particle size.

Sampling for airborne microorganisms falls into three general categories: viable (cultural), particulate and subparticulate. Viable refers to the ability of a particle to grow in the given conditions; sampling efficiency is controlled by culture medium used and culture conditions. Cultural sampling always underestimates actual levels. Viable sampling can include culture plate samplers (suction devices), filter samplers where filters are subsequently cultured, and liquid impingers where air is drawn through a liquid in which particles are entrained following impaction on glass surfaces. The liquid is subsequently cultured. Particulate samplers include rotating impactors and suction devices (e.g., spore traps and filter samplers). Particles are visually identified so that viability underestimates are avoided. Subparticulate sampling, which is used to sample for amorphous biological substances, can utilize filter/suction devices, liquid impingers, or condensers.

Source sampling involves locating emission sites for microorganisms. Samples of contaminated liquid can be taken directly as can samples of dust or other particulate matter. Care must be taken to maintain viability of entrained organisms. Surface sampling includes the use of culture medium (plates) actually touched to surfaces, or sterile swabs wiped on surfaces and subsequently cultured. Identifiable particles can be detected using sticky tape touched on potentially contaminated surfaces. Organismal sampling (both human and animal) includes swabs directly from potentially infected individuals, hair and skin dander samples, and possibly serum, urine, stool, and saliva samples.

Analysis of all samples falls into four general categories: Direct identification, effect analysis, biochemical analysis, and immunological analysis. Direct identification is used where either individual particles or colonies resulting from culture can be directly identified. Individual particles are rarely identifiable when less than 5 μm in diameter. Most colonies are identifiable provided sporulation occurs, but many airborne microorganisms do not form colonies in artificial culture. Effect analysis can be used where an infectious agent is suspected and a suitable test animal is available (e.g., Endotoxin), or after the fact, in the case of epidemics in people or animals where symptoms can be related to specific organisms. Biochemical analysis is appropriate where the biochemical characteristics of the particle or substance are known and assay methods available (e.g., mycotoxins).

Immunological methods, including radio- and enzyme immunoassays, are useful where an immunological effect is suspected, and where known positive serum is available for the assays. Immunological methods are most useful where a specific antigen is of concern, or to demonstrate an immunological response to amorphous substances in symptomatic, exposed patients when specific organisms are not identified.

ADDITIONAL PAPERS

AN AUTOMATED APPROACH FOR AN EMISSIONS TESTING FACILITY

by Andy Blackard (Radian Corporation)

ABSTRACT

An automated approach employing a personal computer has been selected in the design of an emissions testing facility (ETF). The design goals were to automate data collection and reduction, as well as simplify the routine daily operation of the ETF. The benefits afforded by this approach have been a rapid throughput of experimental data and an enhancement of data quality.

The system level design goal for this automated system was to provide an integrated productivity tool for simplifying operation of the emissions testing facility. To accomplish this involved integration of the test system data acquisition and control system operational hardware with corresponding control software. Additionally, data analysis and reporting was facilitated by the use of standard data formats.

In the system being described, the critical experimental values being sensed and recorded include: test temperature, airflow rate, and humidity. The real-time values measured for these experimental parameters are continuously compared to those values in the experimental test matrix selected by the operator. Decisions are then made regarding the necessary adjustments for maintaining these three critical test parameters within prescribed control limits. The control features involved with the airflow rates and the routing of these air streams with control valves are controlled by the automated system. The necessary mechanical adjustments of the thermally controlled chamber and humidification system are communicated to the operator by the screen display of the control program.

COLLECTION AND ANALYSIS OF NICOTINE AS A MARKER FOR ENVIRONMENTAL TOBACCO SMOKE IN PERSONAL SAMPLES

S. Katharine Hammond[1,2], Brian P. Leaderer[3], and Ann Roche[2]

[1]Department of Family and Community Medicine
University of Massachusetts Medical Center
Worcester, Massachusetts 01605

[2]Department of Environmental Science & Physiology
Harvard School of Public Health
Boston, Massachusetts 02115

[3]John B. Pierce Foundation Laboratory and
Yale University School of Medicine, Dept. of Epid. & Publ. Hlth.
New Haven, Connecticut 06519

Suspended particulates in the non-industrial indoor environment exhibit a highly variable size distribution and chemical composition and emanate from a large number of sources. A major contributor to the submicron aerosol indoors is environmental tobacco smoke (ETS). Assessing the contribution of ETS to measured indoor particulate levels requires the identification of a proxy or tracer air contaminant indicative of ETS. Nicotine is a potential marker for ETS because it is unique to tobacco smoke and is a major constituent of the smoke. However, nicotine is very volatile and as such can be lost during sampling. An air sampling method is presented which efficiently collects both particulate and vapor phase nicotine. Two filters are assembled in tandem in a personal sampling cassette. The first filter collects total or size fractional particulates and the second is heated with sodium bisulfate to collect vapor phase nicotine and nicotine which has volatilized from the particulate material collected on the first filter. The nicotine is then desorbed from the filters and analyzed by gas chromatography with nitrogen sensitive detection. The sampling method was evaluated in an environmental chamber under controlled conditions of temperature, humidity, ventilation and smoking rate. It was then employed in a field study of particulate exposures of office workers and railroad mechanics to determine the portion of the particulate exposure attributable to environmental tobacco smoke. The method was found to be efficient and sensitive for the determination of nicotine levels in air.

A PRELIMINARY REPORT ON MATERIALS EVALUATION FOR A NEW OFFICE BUILDING

Hal Levin

University of California, Berkeley
College of Environmental Design
373 Wurster Hall
Berkeley, CA 94720

A broad testing program is in progress for a large new office building in California. Tests have been conducted on materials and components of furnishings and on air quality indoors in the initially occupied spaces of the phased building project.

In some instances, potential products have been tested prior to selection to assist designers in choosing stable, non-toxic or non-irritating products. Other materials have been screened by reviewing Manufacturer's Safety Data Sheets (MSDS) to identify potentially problematic substances. Discussions with manufacturers and suppliers of some products have resulted in modifications intended to reduce unstable chemical content or emissions inside the completed structure. Test results have been used to predict indoor pollutant concentrations in the completed building.

Tests have been conducted using an environmental chamber, bulk testing, and headspace sampling. Variations in temperature have been used to assist in the prediction of emission rates in the building environment and to form the basis for recommended ventilation system protocols.

Results from various test methods are consistent with each other and comparable to tests conducted elsewhere for certain products. The age of materials being tested has been known within reasonable limits and results confirm the significance of age on emission rates and material content. Of particular interest is the very rapid decline in formaldehyde content and emission rates for carpet samples.

The work identifies significant contributions material testing can make to building design, material selection, and mechanical system operations. Further work is needed to identify organic compounds and validate temperature effect testing.

ALTERNATIVE METHODOLOGIES FOR EMISSIONS CHARACTERIZATION OF UNVENTED SPACE HEATERS

Robert A. Macriss

Institute of Gas Technology
Chicago, Illinois 60616

Three alternative methodologies have been evaluated for emission factor measurements from unvented space heaters. The 6 heaters tested have covered typical ranges of fuel input rate and of burner design. Preliminary statistical analyses of the data obtained have also been completed. Potential interferences in the method(s) of measurement have been identified and resolution of apparent problem areas could lead to the initial selection of a preferred methodology.

Studies on the Mutagenicity of Sidestream Cigarette Smoke Particles

Randall S. Morin

Sidestream cigarette smoke particles were generated by allowing a generic brand of US manufactured king size filter cigarettes to burn inside a plexiglas chamber. The air inside the chamber was exhausted using a vacuum pump and pulled across glass fiber filters. The collected particles were extracted from the filters by either Soxhlet extraction or ultrasonic agitation using one of three solvents (dichloromethane, methanol, or acetone).

The extracts were concentrated, solvent-exchanged into DMSO and tested for mutagenic activity in the Ames Salmonella reverse mutation assay. Each sample was tested in strains TA98 and TA100 with and without metabolic activation (S9). The mutagenic activity was calculated using the non-linear model of Stead et al. (1981) and expressed in revertants per cigarette. The highest activity was observed in TA98 with S9 and in TA100 without S9.

Both Soxhlet extraction and sonication were found to be effective methods of extracting those compounds that are mutagenic in the Ames test. Of the three solvents, the use of acetone resulted in levels of mutagenic activity in TA100 without S9 that were significantly higher than when either dichloromethane or methanol were used.

The effect of refluxing on the mutagenic activity of sidesteam cigarette smoke particles was also examined. Replicate samples were extracted using sonication and acetone and then refluxed for 0, 8, 16, 24 h. No significant change in activity was seen in TA98 with S9. A significant time-dependent decrease in activity was seen, however, in TA100 without S9.

The effect of storage on the mutagenic activity of sidestream cigarette smoke particles was also examined. Sidestream cigarette smoke particles and extracts were stored for different lengths of time after which the samples were tested for mutagenic activity. Significant decreases in activity were seen after storage as either particles or extracts in DMSO. The largest decrease in activity was observed in TA100 without metabolic activation after storage as an extract in DMSO.

CHARACTERIZATION OF CONTAMINANT EMISSIONS
FROM INDOOR SOURCES

May 13,-15, 1985

Chapel Hill, North Carolina

Conference Chairman

* Dr. Brian P. Leaderer
John B. Pierce Foundation Lab, Inc.
290 Congress Avenue
New Haven, CT 06519
(203)562-9901

Sessions Chairmen

I. Dr. W. Gene Tucker
Chief, HATB (MD-54)
U.S. EPA, AEERL
Research Triangle Park, NC 27711
(919)541-2746

II. Dr. Lars Mølhave
Hygiejnisk Institut
Aarhus Universitet
Bygning 180 Universitetsparken
DR 8000 AARHUS C
DENMARK
001-45-6-128288

III. Dr. David Grimsrud
Lawrence Berkeley Laboratory
Building Ventilation and
Indoor Air Group
1 Cyclotron Road (B44B)
Berkeley, CA 94720
(415)486-4023

IV. Dr. Jan A. J. Stolwijk
Dept. of Epidemiology & Public Health
Yale University School of Medicine
60 College Street
New Haven, CT 06510
(203)785-2867

V. Dr. Helmut Knöppel
Head, Environmental Chemicals Sector
Commission of European Communities
Joint Research Center
1-21020 Ispra (Varese)
ITALY
011-39-0332-789204
789111

Attendees

* Mr. Andy Blackard
Radian Corporation
P. O. Box 13000
Research Triangle Park, NC 27709
(919)481-0212

Mr. Steven Bromberg
U.S. EPA, EMSL (MD-75)
Research Triangle Park, NC 27711
(919)541-2919

* Dr. Harriet Burge
R6621, Kresge 1
Box 056
U. of Michigan Medical Center
Ann Arbor, MI 48109
(313)764-0227

* Dr. William Cain
John B. Pierce Foundation Lab, Inc.
290 Congress Avenue
New Haven, CT 06519
(203)562-9901

Dr. Larry Claxton
U.S. EPA, HERL
Research Triangle Park, NC 27711
(919)541-2329

* Dr. Cliff Davidson
Dept. of Civil Engineering
Carnegie-Mellon University
Schenley Park
Pittsburgh, PA 15213
(412)578-2940

Dr. Russell Dietz
Dept. of Applied Science
Building 426
Brookhaven National Laboratory
Upton, Long Island, NY 11973
(516)282-3059

* Dr. James E. Dunn
Chairman, Statistics Division
University of Arkansas
301 Science-Engineering Building
Fayetteville, AR 72701
(501)575-3351

* Dr. John Girman
Building Ventilation
and Indoor Air Group
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, CA 94720
(415)486-4668

Dr. Sumio Goto
U.S. EPA, HERL
Research Triangle Park, NC 27711
(919)541-2815

* Dr. Michael Guerin
Oak Ridge National Laboratory
Building 4500 South, Room E160
Oak Ridge, TN 37831
(615)574-4862

Dr. Kailash Gupta
Consumer Products Safety Commission
Westbard Towers Building
5401 Westbard Avenue
Bethesda, MD 20816
(301)492-6887

* Dr. William Gutknecht
Research Triangle Institute
P. O. Box 12194
Research Triangle Park, NC 27709
(919)541-6000

* Dr. S. Katherine Hammond
Dept. of Family and Community Medicine
U. of Mass. Medical Center
55 Lake Avenue, North
Worcester, MA 01605
(617)856-5636

* Mr. David P. Harlos
Dept. of Environmental Science
and Physiology, Room 1305
Harvard School of Public Health
665 Huntington Avenue
Boston, MA 02115
(617)732-1255

* Dr. Tyler D. Hartwell
Research Triangle Institute
P. O. Box 12194
Research Triangle Park, NC 27709
(919)541-6453

* Dr. Alan R. Hawthorne
Health & Safety Research Division
Building 4500S MS S258
Oak Ridge National Laboratory
Oak Ridge, TN 37831
(615)574-6246

Mr. Steven Hayward
Indoor Air Quality Program
California Dept. of Health Services
2151 Berkeley Way
Berkeley, CA 94704
(415)540-3161

Mr. John E. Janssen
Honeywell Control Systems
1000 Boone Ave., North
Golden Valley, MN 55427
(612)541-6751

Mr. Jeff Keever
Research Triangle Institute
P. O. Box 12194
Research Triangle Park, NC 27709
(919)541-6000

Mr. Michael Kosusko
Hazardous Air Technology Branch
U.S. EPA, AEERL (MD-54)
Research Triangle Park, NC 27709
(919)541-1528

* Mr. Hal Levin
University of California
390D Wurster Hall
Berkeley, CA 94720
(415)642-2896

Dr. Robert G. Lewis
EPA, EMSL (MD-44)
Research Triangle Park, NC 27711
(919)541-3065

* Dr. Joellen Lewtas
U.S. EPA, HERL (MD-68)
Research Triangle Park, NC 27711
(919)541-3849

Dr. James Lodge
Editor, "Atmospheric Environment"
385 Broadway
Boulder, CO 80303
(303)449-7712

* Mr. Robert Macriss
Institute of Gas Technology
3424 South State Street
Chicago, IL 60616
(312)567-3930

Dr. David T. Mage
U.S. EPA, EMSL (MD-56)
Research Triangle Park, NC 27711
(919)541-3184

Mr. Robert F. Martz
Acurex Corporation
P. O. Box 13109
Research Triangle Park, NC 27709
(919)541-2340

Mr. Mark Mason
Acurex Corporation
P. O. Box 13109
Research Triangle Park, NC 27709
(919)541-2850

* Dr. Thomas Matthews
Health & Safety Research Division
Oak Ridge National Laboratory
Oak Ridge, TN 37831
(615)574-6248

Dr. William A. McClenny
U.S. EPA, EMSL (MD-44)
Research Triangle Park, NC 27711
(919)541-3158

Dr. Raymond G. Merrill
U.S. EPA, AEERL (MD-62)
Research Triangle Park, NC 27711
(919)541-2558

* Mr. Randall S. Morin
U.S. EPA, HERL (MD-68)
Research Triangle Park, NC 27711
(919)541-2815

* Dr. Demetrios J. Moschandreas
IITRI
10 West 35th Street
Chicago, IL 60616
(312)567-4301

Ms. Judy S. Mumford
U.S. EPA, HERL (MD-68)
Research Triangle Park, NC 27711
(919)541-3095

* Dr. Leonard Nelms
Acurex Corporation
P. O. Box 13109
Research Triangle Park, NC 27709
(919)541-2629

Ms. Carolyn Norris
Acurex Corporation
P. O. Box 13109
Research Triangle Park, NC 27709
(919)541-2850

Mr. Everett L. Plyler
U.S. EPA, AEERL (MD-61)
Research Triangle Park, NC 27711
(919)541-2918

* Mr. Warren Porter
Consumer Products Safety Commission
Westbard Towers Building
5401 Westbard Avenue
Bethesda, MD 20816
(301)492-6477

Mr. Frank T. Princiotta
Director, AEERL (MD-60)
U.S. EPA
Research Triangle Park, NC 27711
(919)541-2821

Mr. James Quackenboss
Section on Pulmonary Diseases
University of Arizona Medical Center
Tucson, AZ 85724
(609)626-6379

Mr. Harry E. Rector
Geomet Technologies, Inc.
20251 Century Boulevard
Germantown, MD 20874
(301)428-9898

Dr. Susan Rose
Office of Energy Research
E.R. 73
U.S. Department of Energy
Washington, DC 20545
(301)353-4731

Mr. John S. Ruppersberger
Hazardous Air Technology Branch
U.S. EPA, AEERL
Research Triangle Park, NC 27711
(919)541-2734

* Mr. David Sanchez
Hazardous Air Technology Branch
U.S. EPA, AEERL (MD-54)
Research Triangle Park, NC 27711
(919)541-2979

* Dr. Bernd Seifert
Institut fur Wasser Boden
und Lufthygiene des
Bundesgesundheitsamtes
Postfach 330013
D-1000 Berlin 33
West Germany
011-49-30-83082734 (office)
-7916197 (home)

* Dr. Ken Sexton
Health Effects Institute
215 First Street
Cambridge, MA 02142
(415)540-3161

* Dr. Richard Sextro
Building Ventilation and
Indoor Air Group
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, CA 94720
(415)451-4000

* Dr. Linda Sheldon
Research Triangle Institute
P. O. Box 12194
Research Triangle Park, NC 27709
(919)541-6603

* Dr. Joseph Sickles
Research Triangle Institute
P. O. Box 12194
Research Triangle Park, NC 27709
(919)541-6000

*Primary author of conference paper

Kent Thomas
Research Triangle Institute
P. O. Box 12194
Research Triangle Park, NC 27709
(919)541-6000

* Mr. Gregory Traynor
Building Ventilation and
Indoor Air Group
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, CA 94720
(415)486-4023

* Dr. Lance Wallace
Dept. of Environmental Science
and Physiology
Harvard School of Public Health
665 Huntington Avenue
Boston, MA 02115
(617)732-0977

Dr. Nancy K. Wilson
U.S. EPA, EMSL (MD-44)
Research Triangle Park, NC 27711
(919)541-4723

Mr. John E. Yocom
TRC Environmental Consultants
800 Connecticut Boulevard
East Hartford, CT 06108
(203)289-8631

Conference Co-Sponsor:

Dr. Cary Young
Environmental Assessment Dept.
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, CA 94303
(415)855-2519/2724